Comparison of snow covered vegetation and ground on Grand Mesa with UWScat

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Introduction

The ability to measure the amount of water stored in Earth's terrestrial snowpack is important for human development, resource management, and environmental modelling. Active microwave remote sensing offers the promise to do so however a better understanding of how forest, which accounts for a large fraction of snow-covered land, affects the microwave retrieval of snow water equivalent (SWE) is needed. This is a fundamental goal of the NASA SnowEx mission and one we address using data collected wth UWScat during the February 2017 campaign in Grand Mesa, Colorado. UWScat (Figure 1) is a dual frequenciy polarimetric ground-based radar scatterometer which operate at 9.6 and 17.2 GHz. The system scans through an operator-defined set of azimuth and elevation angles and averages the radar return for each azimuth sweep. UWScat provides backscatter (VV, HH, VH, HV), range profiles, and polarization data for each elevation angle. System parameters are provided in Table 1.

Table 1. UWScat parameters..

Parameter	Ku	X
RF output frequency (GHz)	16.95-17.45	9.35-9.85
Centre frequency (GHz)	17.2	9.6
Transmit power, narrow beam (dBm)	-8	-11.8
Transmit bandwidth (MHz)	500	500
Range Resolution (m)	0.3	0.3
Antenna beamwidth, narrow beam (°)	5.6	4.3
Cross-polarization isolation (dB)	>30	>30
Transmit/receive polarizations (linear)	VV, HH, VH, HV	VV, HH, VH, HV
Sensitivity (dB m^2m^{-2})	-50	-50

Figure 1. UWScat deployed on 02/22/2017 (left) and on a Skyjack on 02/24/2017.

Sites & methods

UWScat was deployed from February 21 to February 25, at 8 sites. The map in Figure 2 shows the locations of observation sites. Left panel shows LSOS site and right panel shows sites on Grand Mesas. Table 2 provides a brief description of each site and scan parameters employed.

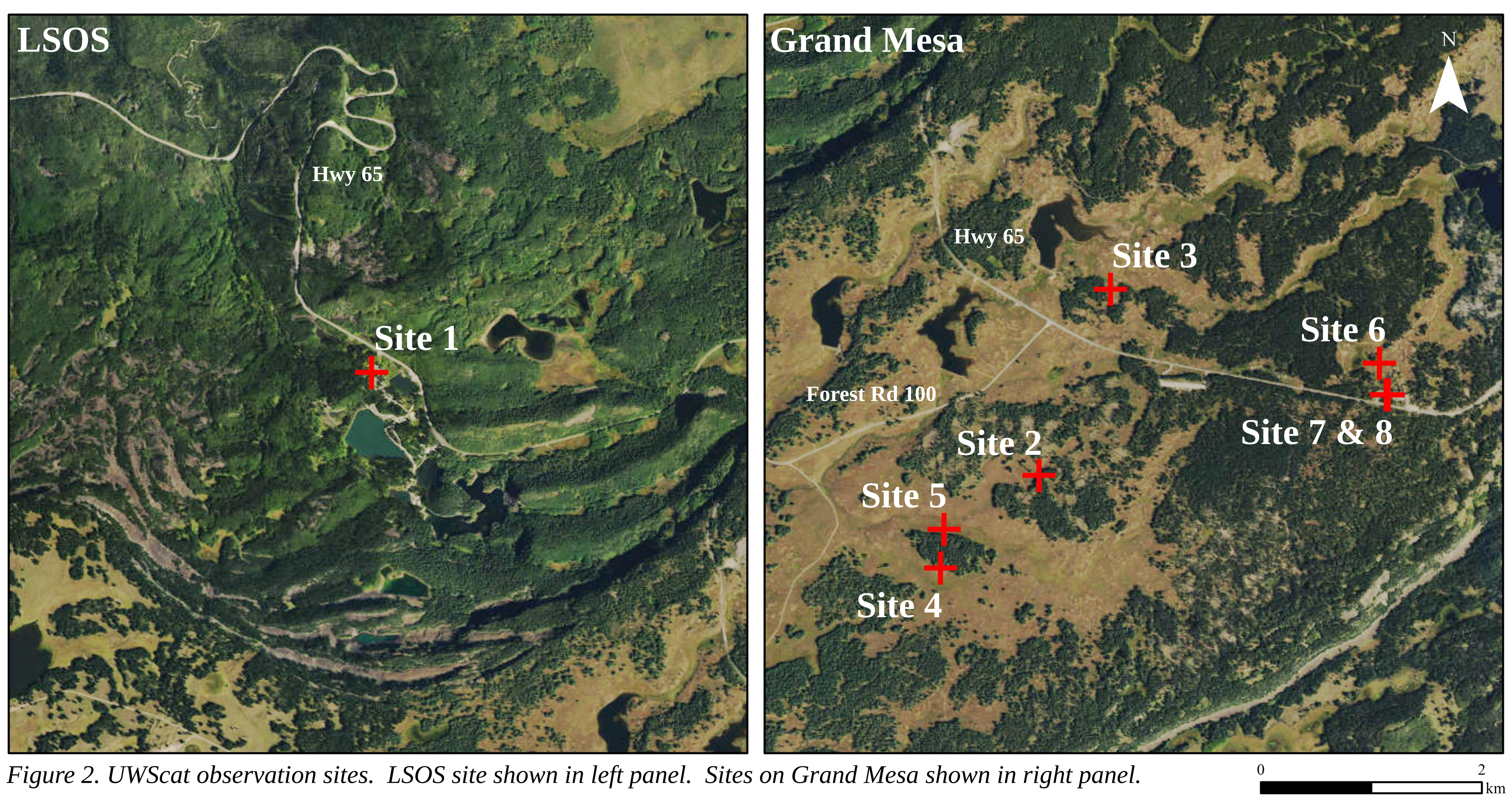


Figure 2. UWScat observation sites. LSOS site shown in left panel. Sites on Grand Mesa shown in right panel.

Table 2. Site description and UWScat scan parameters.

Site	Date	Site description	Azimuth	Elevation	Notes
1	21-Feb-17	grass, low vegetation, near U of M truck	20° to -20°	25° to 61°, 3° steps	warm air, signs of melting
2	22-Feb-17	grass, low vegetation	30° to -30°	25° to 65°, 3° steps	
3	22-Feb-17	grass, low vegetation	30° to -30°	25° to 65°, 3° steps	
4	23-Feb-17	grass, low vegetation	30° to -30°	25° to 65°, 3° steps	high winds buffeting scatterometer
5	23-Feb-17	grass, low vegetation	30° to -30°	25° to 65°, 3° steps	
6	24-Feb-17	grass, low vegetation, mega pit site	30° to -30°	25° to 65°, 3° steps	
7	24-Feb-17	grass, low vegetation, coniferous	30° to -30°	25° to 65°, 3° steps	UWScat mounted on Skyjack 9 m above ground
8	25-Feb-17	grass, low vegetation, coniferous	20° to -40°	25° to 65°, 3° steps	UWScat mounted on Skyjack 9 m above ground

Results

A comparison of angular backscatter response for a tree-free site with that of a forested site is shown in Figure 3, illustrating the difficulty of relying on backscatter alone to interpret the radar response and distinguish between different targets. Both sites show similar magnitudes and angular response.

The range profiles in Figure 4 help to identify the nature of the scatterering. In the tree-free profile, the peaks are relatively well defined as the snowpack has a less complex structure than the forest canopy. The forested profile shows an ambiguous, broad shape with no dominant peak. The peak range of the forested site is greater than that of the tree-free site because UWScat was mounted 9 m above the ground.

The polarization histograms in Figure 4 provide information on the polarization state of the scattered wave. In the case of the tree-free site at both frequencies there is less depolarization evident in the relatively well-defined peaks centred in the region of the plot corresponding with the transmitted wave polarization. The histograms of the forested site show depolarization occurring as the scattered wave polarization state spans the range of Ψ and X at both frequencies. Given a longer wavelength, X-band often shows less depolarization than Ku-band, especially in the tree-free sites. This may help to distinguish forested sites from tree-free sites and is a benefit of the dual frequency approach. However given the inhomogeneous structure of forest canopy, and some snow, depolarization may vary.

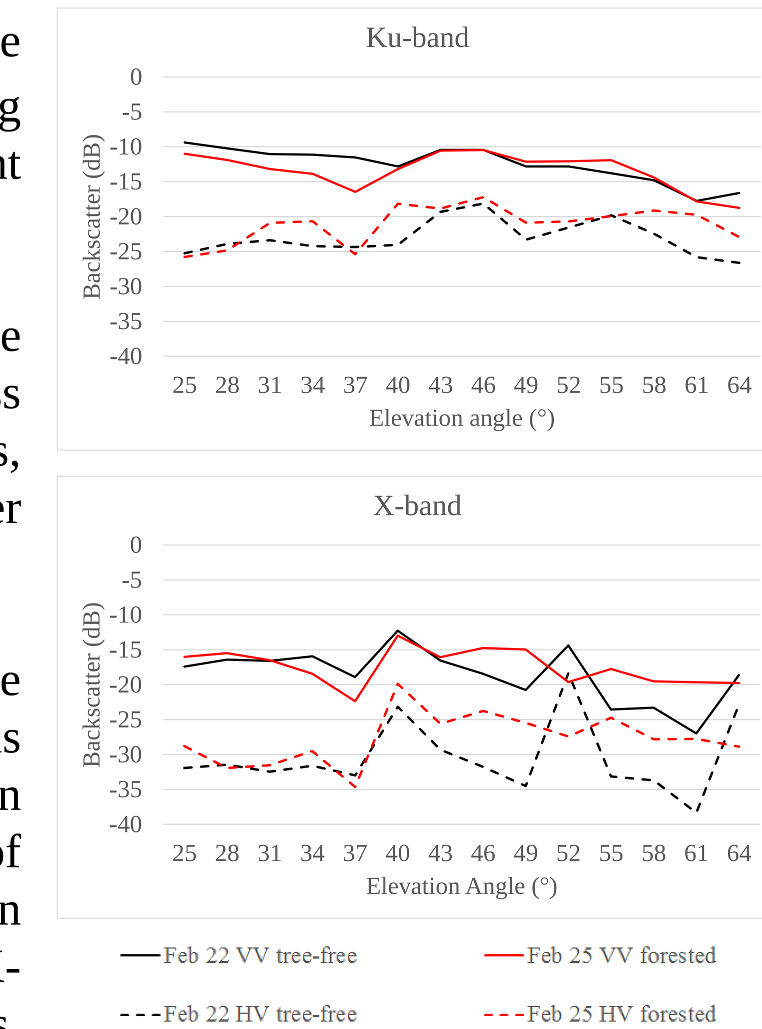
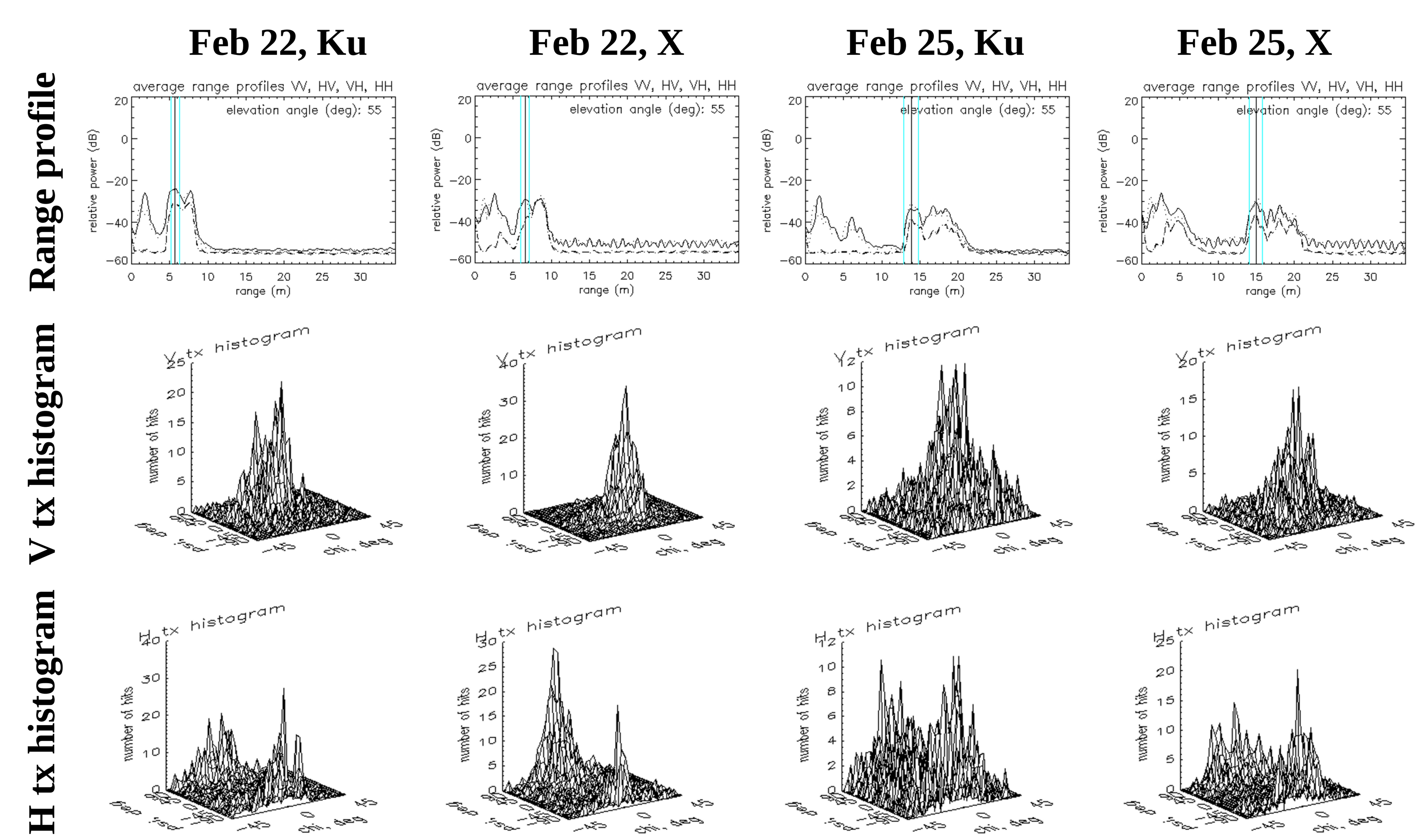


Figure 3. Angular response for a tree-free and forested site at Ku-band (top) and X-band (bottom).



Understanding the axes

The x- and y- axis of the polarization plots represent the ellipticity (X) and orientation (Ψ) as defined by the polarization ellipse in [1]. Vertical and horizontal orientation occurs when Ψ is 0° and -90° or 90°, respectively. Linear polarization occurs when X is 0° while circular polarization occurs when X is -45° or 45°.

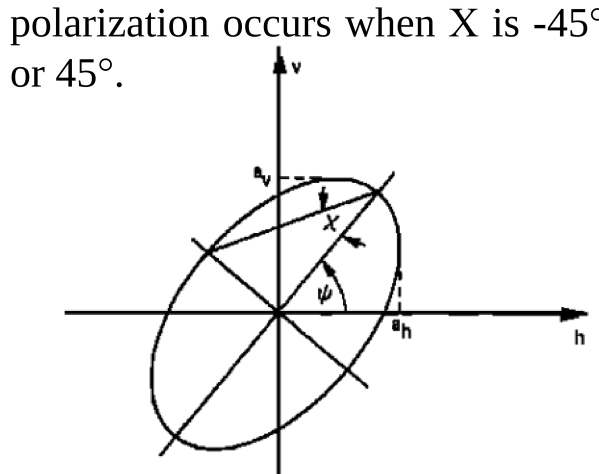


Figure 4. UWScat data products: range profiles (top row), vertical transmit polarization histograms (middle row), and horizontal transmit polarization histograms (bottom row). Columns 1 and 2 represent a tree-free site and columns 3 and 4 represent a forested site. Polarization ellipse from [1].

Conclusions

UWScat has provided a useful suite of data including the backscatter and polarimetric response at forested and tree-free sites during the 2017 SnowEx field campaign. These results show promise for distinguishing the presence of forest and have highlighted the strength of the dual frequency approach. As a next step, combining coincident snow microstructure data with these results will provide useful insights that increase our understanding of the radar response from SWE in a forested landscape using a dual frequency Ku and X-band active microwave system.

References

[1] van Zyl, J.J., Zebker, H.A., & Elachi, C. (1987). Imaging radar polarization signatures: Theory and observation. *Radio Science 22:4.*